USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Effectiveness of Streamside Management Zones in Protecting Aquatic Habitat in Timber Management Areas

Focus Categories: NPP, WQL, MET

Keywords: Water quality, Nonpoint Source pollution, Silvicultural Best Management Practices, Streamside Management Zones, Bioindicators, Biomonitoring, Aquatic macroinvertebrates, Riparian vegetation, Streams, Water quality monitoring

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Federal Funds Requested: $13,088

Non-Federal (matching) Funds Pledged: $26,176

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Congressional District of University Where the Research is to be Conducted: 3rd Mississippi Congressional District

Statement of Critical Regional Water Problems

The Federal Water Pollution Control Act of 1972, the Clean Water Act of 1977, and the Water Quality Act of 1987 (Section 319) collectively provide federal legislation designed to control nonpoint source (NPS) water pollution. In response, states in the southern U.S. have designed Best Management Practices (BMPs) to minimize the impacts of forestry practices on water quality. Forestry practices such as harvesting may result in soil erosion, nutrient loss, and resultant NPS pollution in the form of sediment and nutrient delivery to streams that not only produce potential degradation of water quality, but also can potentially alter aquatic habitat and endanger aquatic biota.

Streamside management zones (SMZs), designed to provide intact or selectively harvested forest buffers between silvicultural activities and adjacent streams, are being used as a component of BMPs to maintain streamwater quality, aquatic habitat, and aquatic biota by minimizing streamwater temperature changes and the transport of sediments, nutrients, and pesticides into surface waters. However, scientifically-based assessment of effectiveness of these measures, particularly in relation to protection of aquatic habitat and maintenance of aquatic communities, has been lacking because monitoring programs have not been widely implemented. If landowners are expected to enthusiastically incorporate SMZs into their forest management protocols, then it is necessary to quantify the benefits of this practice in forested watersheds of Mississippi.

Statement of the Results, Benefits, and Information Expected From This Project

The central hypothesis to be tested by this project is that SMZs effectively protect streamwater quality, aquatic habitat, and aquatic biota from forest-harvesting operations in the Upper Coastal Plain region of Mississippi. Specific hypotheses to be evaluated include: (1) increased width of SMZs will improve SMZ effectiveness ; (2) SMZ effectiveness is a function of upslope harvesting practices, slope steepness, soil erodibility, size of harvesting operation, and residual overstory within the SMZ; and (3) relationships between SMZ characteristics and streamwater quality, aquatic habitat, and aquatic biota will diminish over time since harvesting. Data collected from at least 30 logging operations with a range of existing SMZs on perennial streams during the two years of the proposed study will be used to test these hypotheses.

The findings of this project will be used to support the implementation of NPS abatement programs such as silvicultural BMPs in Mississippi. Specifically, this project will provide a quantitative measure of the effectiveness of SMZs for mitigation of erosion, sedimentation and subsequent impacts on aquatic habitat and communities in association with forest-harvesting activities. The research watersheds proposed for evaluation will be utilized as demonstration areas for silvicultural BMP workshops and related technology-transfer activities conducted by personnel from Mississippi State University, government agencies, and private timber companies. Research results will be presented at regional and national scientific meetings, submitted for publication in peer-reviewed journals, and made available to the public. This study will also provide training in forest management and policy, forest hydrology, silviculture, and stream ecology for graduate and undergraduate students who are initiating careers in natural resource management.

Nature, Scope, and Objectives of the Research:

Silvicultural best management practices (BMPs) have been widely accepted as effective management tools to minimize nonpoint source (NPS) pollution associated with forest management activities. However, scientifically-based assessment of effectiveness of these measures, particularly in relation to protection of aquatic habitat and maintenance of aquatic communities, has been lacking because monitoring programs have not been widely implemented. Streamside management zones (SMZs) are commonly implemented to protect aquatic functions and values. But decisions regarding SMZ width and intensity of harvesting within SMZs can still benefit from evaluations of the responses of aquatic habitats and the communities they support to SMZ alternatives. Acquiring quantitative information of effectiveness across an array of SMZ widths and levels of management activities within SMZs will enhance our ability to improve these management practices and thus help achieve or maintain sustainable forest management systems.

Evaluation of SMZs has traditionally relied on assessing physicochemical responses of the stream (Comerford, et al., 1992). However, this approach is limited because sampling is usually done at one point spatially and temporally and many of the metrics can vary over time scales of hours. As such, spatial and temporal variations in physicochemical properties can mask responses to forest management activities occurring upslope from

the stream. Combining physicochemical, habitat assessment, and biomonitoring offers a more powerful tool to accurately evaluate SMZ effectiveness.

The overall objective of the proposed study is to evaluate the effectiveness of different 1) SMZ widths, 2) residual amounts of residual overstory within SMZs, and 3) amounts of time since implementation of SMZs currently used on intensively managed loblolly pine (*Pinus taeda*) plantations in Mississippi. This study will also determine relationships between SMZ characteristics and responses of physicochemical, habitat, and biotic stream properties. Outcomes of the proposed research will enable forest managers to modify ineffective BMPs and to promote BMPs which are meeting management goals.

Null Hypotheses

H_{01}: Width of SMZ does not affect SMZ effectiveness in protecting water quality, aquatic habitat, and aquatic macroinvertebrate communities.

H_{02}: Residual overstory within SMZs does not influence SMZ effectiveness in protecting water quality, aquatic habitat, and aquatic macroinvertebrate communities.

H_{03}: Effectiveness of SMZs for protecting water quality, aquatic habitat, and macroinvertebrate communities is not influenced by amount of time since timber harvesting.

Methods, Procedures, and Facilities

Evaluation of SMZ effectiveness will rely on access to management records of ownership within Mississippi where timber harvesting of loblolly pine plantations with varying widths of SMZs and logging intensities within SMZs have been implemented within the past three years. Watersheds with streamflow which occurs for a minimum of eight months will be selected for initial screening.

Our goal is to locate perennial streams adjacent to forest management areas that have:

1. varying widths of SMZs;

2. varying degrees of residual overstory within SMZs;

3. varying size of adjacent timber harvesting areas;

4. three ages since SMZ implementation: current year, one year ago, two years ago; and

5. upstream reaches that are relatively undisturbed by recent logging activity.

We will work in collaboration with Weyerhaeuser Corporation to develop a matrix of forest management sites that represents the full range of existing SMZ characteristics within their Mississippi landbase. A minimum of 10 sites from each of three age

categories will be selected to evaluate relationships between SMZ characteristics and stream responses. The combination of SMZ width, residual overstory within an SMZ, size of adjacent timber harvesting area, and age since implementation is designed to provide a full array of field conditions to assess SMZ effectiveness.

Aquatic invertebrate communities, stream habitat assessments, and traditional measurements of water quality, including total suspended sediments, nitrate, and orthophosphates have been shown to be relatively sensitive and practical indicators of BMP effectiveness (Adams, et.al., 1995; O'Neil and Shepard 1996; Dissmeyer, 1994). As such, biomonitoring of aquatic macroinvertebrate communities, stream habitat assessment, and point sampling of water quality will all be conducted at one sampling station upstream adjacent to areas where timber has not been harvested and one sampling station downstream from forest management areas that have been harvested within the past three years and have received some level of SMZ implementation. Three replicate subsamples for assessment of water quality, aquatic habitat, and macroinvertebrate communities will be measured at each upstream and downstream sampling station on a given date to minimize sources of temporal variation. Sampling will be conducted during periods of base flow. The upstream sampling station will serve as a reference and will provide a range of stream conditions occurring in the absence of forest harvesting. The upstream station is measured to provide a database containing acceptable ranges representing best attainable physical habitat, water chemistry, and biological parameters for specific local environmental conditions. Effectiveness of SMZs will be assessed by determining percent similarity between upstream (reference) and downstream properties in relation to SMZ characteristics. Multiple regression procedures will be employed to study relationships between SMZ characteristics (independent variables) and changes in stream properties between upstream and downstream reaches (dependent variables).

Basic protocols for rapid habitat assessment, bioassessment, and physicochemical assessment for streams and rivers as outlined by Plafkin, et al. (1989) will be followed. Habitat evaluations will be based on: 1. Cover, 2. Canopy, 3. Channel condition, 4. Pool/riffle ratio, 5. Bank stability, and 6. Riparian vegetation condition. Potential metrics of the macroinvertebrate community that will be used include: 1. Taxa richness, 2. Family biotic indices, 3. Diversity indices, 4. Ratio of scraper and filtering collector functional feeder groups, 5. Ephemeroptera, Plecoptera, and Trichoptera (EPT) index, 6. Ratio of EPT and Chironomidae abundances, 7. Percent contribution of dominant taxon (measurement of evenness), 8. Community similarity indices, and 9. Functional group ratios in coarse particulate organic matter found in streams. Evaluation of each macroinvertebrate sample will be based on subsamples of 100 organisms differentiated to the lowest positively identified taxonomic level in the laboratory.

Benthic macroinvertebrates will be quantified using a hand-held coring device (Miller and Bingham 1987). The macroinvertebrates will be preserved in the field with buffered 10% formalin, and rose bengal stain and an elutriation process will help separate the organisms from the sediment (Payne et al. 1991).

Physicochemical parameters to be measured in the field include dissolved oxygen, pH, water temperature, velocity, turbidity, and electrical conductivity using standard techniques (APHA 1989). Total suspended sediments, nitrate, sulfate, and phosphate will be measured in the laboratory using standard techniques (APHA 1989). Grain-size analysis of sediments collected in the coring device will be determined with a standard set of U.S. Geological Survey sieves. Organic content of these sediments will be measured as the difference in mass after a complete drying at 65 C followed by heating in a muffle furnace at 550 C for 24 hrs (Payne and Miller 1991).

The Forest and Wildlife Research Center at Mississippi State University has state-of-the-art facilities that can accommodate all aspects of the proposed study, including field and laboratory procedures, spatial information technological needs, and computer support.

Forest Hydrology Laboratory Equipment

Forest and Wildlife Research Center

Mississippi State University

Dionex DX-500 Ion Chromatograph

Fisons NA 1500 NCS Dry Combustion Analyzer

Milton-Roy Spectronic 501 Spectrophotometer

Technicon Autoanalyzer II Colorimetry System

Mettler-Toledo PB3002 Top Loading Balance

Mettler AE-200 Analytical Balance

Sartorius M2P Microbalance

Fisher Accumet 925 pH/Ion Meter

2 Aqua-Check Portable Water Analyzers (pH, TDS, dissolved oxygen, temp)

LaMotte Model 2008 Portable Turbidimeter

Monitek Model 21PE Portable Turbidimeter

5 Drying Ovens

2 Refrigerators

Walk-in Cooler

Walk-in Freezer

6 Computers

Related Research

The literature that specifically reports on the effectiveness of SMZs to maintain water quality adjacent to forestry operations is sparse. Comerford, et al. (1992) synthesized buffer strip research results aimed to determine effectiveness. They pointed out that most studies of streamside buffer strips have been conducted adjacent to cultivated agricultural lands (Lowrance et al., 1986; Cooper et al. 1987; Cooper and Gilliam 1987; Peterjohn and Correll 1984; Phillips 1989). These studies of agricultural settings quantified the amounts of sediment and nutrients removed by forested buffer strips but did not directly quantify changes in streamwater quality.

Martin and Pierce (1980) studied SMZ effectiveness in harvested forested watersheds at the Hubbard Brook Experimental Forest in New Hampshire and found that nitrate and calcium concentrations in streams were reduced when SMZs were used. They also found that the time for nutrient concentrations to return to background levels was decreased in watersheds with SMZs. In a survey of clearcutting in New England, Martin et al. (1985) recommended buffer strips of at least 10 meters to minimize impacts on stream chemistry, temperature, and light. Swift (1986) recommended increased buffer widths with increasing slope or disturbance in association with construction of forest roads in the southern Appalachians to minimize sediment transport to streams. Hopmans et al. (1987) reported that clearing native eucalypt forests for conversion to radiata pine (*Pinus radiata*) plantations in Australia had little effect on streamwater quality when 30-meter-wide buffer strips were retained along stream channels. Keim and Schoenholtz (in press) reported that SMZ effectiveness in protecting 1st-order streams in the loessial bluff region of Mississippi was largely a function of a disturbance zone within five meters of streams banks. They identified disturbances along stream banks as the most important consideration in designing SMZs in steeply-sloped loessial soils with a prevalence of overland flow occurring in gullies and rills.

Evaluations of aquatic habitat and benthic macroinvertebrate communities have proven practical and sensitive to management activities (Adams, et al., 1995; Plafkin, et al., 1989, O'Neil and Shepard, 1996). This is because biological communities reflect overall ecological integrity and integrate effects of different pollutant stressors over time (Plafkin et al 1989). Results of a study by Adams, et al. (1995) on 27 harvested sites in South Carolina show that stream habitat assessment and a benthic macroinvertebrate bioassessment can accurately evaluate BMP effectiveness. Macroinvertebrate community structure is directly linked to the riparian zone in terms of available stream habitat and food sources. Reports by Adams et al. (1995), O'Neil and Shepard (1996), Dissmeyer (1994), MacDonald (1991), and Plafkin et al. (1989) substantiate the sensitivity of benthic macroinvertebrates to changes in habitat and water quality.

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